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1. Your reference

10029

2. Patent application number

(The Patent Office will fill in this part)

0315251.9

30 JUN 2003

3. Full name, address and postcode of the or of each applicant (*underline all surnames*)

BP EXPLORATION OPERATING COMPANY LIMITED  
BRITANNIC HOUSE, 1 FINSBURY CIRCUS  
LONDON EC2M 7BA, UNITED KINGDOM  
and 62259160002

Patents ADP number (*if you know it*)

XL TECHNOLOGY LIMITED  
GIBB HOUSE, KENNEL RIDE, ASCOT  
BERKSHIRE, SL5 7NT, UNITED KINGDOM  
7925142001

4. Title of the invention

DEVICE

5. Name of your agent (*if you have one*)

COLLINS, Frances Mary

"Address for service" in the United Kingdom to which all correspondence should be sent (*including the postcode*)

BP INTERNATIONAL LIMITED  
PATENTS & AGREEMENTS  
CHERTSEY ROAD,  
SUNBURY-ON-THAMES  
MIDDLESEX  
TW16 7LN  
United Kingdom

Patents ADP number (*if you know it*)

70934 38001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (*if you know it*) the or each application number

Country	Priority application number ( <i>if you know it</i> )	Date of filing (day / month / year)
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7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing (day / month / year)
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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (*Answer Yes if:*

YES

- a) *any applicant named in part 3 is not an inventor, or*
- b) *there is an inventor who is not named as an applicant, or*
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Patents Form 1/77

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Description

11

Claim(s)

-

Abstract

-

Drawing(s)

6 + 6

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Priority documents

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Statement of inventorship and right to grant of a patent (*Patents Form 7/77*)

Request for preliminary examination and search (*Patents Form 9/77*)

Request for substantive examination  
(*Patents Form 10/77*)

Any other documents  
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11.

I/We request the grant of a patent on the basis of this application.

Signature F. M. Collins.  
COLLINS, Frances Mary

Date 30.06.2003

12. Name and daytime telephone number of person to contact in the United Kingdom

01932 763206

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DEVICE

The present invention relates to the installation of patches in a wellbore that penetrates a hydrocarbon bearing formation.

- In the course of completing an oil and/or gas well, it is common practice to run a string of protective casing into the well bore and then to run production tubing
- 5     inside the casing. The annulus between the casing and the surrounding formation is then sealed with a deposit of cement to prevent fluid from flowing through the annulus from one formation zone to another. If the casing traverses a hydrocarbon-bearing zone of the formation, the casing is perforated to create flow apertures through the casing and cement so that the formation fluids can flow into the well.
- 10    Such perforations may subsequently be sealed using an expandable sealing member, preferably in the form of a radially expandable tubular metal patch lowered into the wellbore through the production tubing on a conventional patch setting tool. A patch may also be used to seal holes in the casing caused by corrosion or to reinforce corroded casing sections which have not yet become perforated. Still other
- 15    applications, such as bridging the gap between sections of parted casing will also be apparent to those skilled in the art. In some completions, however, the wellbore is uncased, and an open face is established across the hydrocarbon bearing zone. A patch may also be used in such open face wellbores in order to increase the mechanical strength of the wellbore wall or to seal off a water-producing zone.
- 20    Where the patch is used to increase the mechanical strength of the wellbore wall, the patch is subsequently perforated where it traverses a hydrocarbon bearing zone of the formation.

According to US 2003/0015246, perhaps the most common prior art approach to sealing perforations in a casing has been to use a patch comprising a cylindrical steel sleeve with a rubber-like gasket material bonded to the outer surface of the steel sleeve. Generally, for deployment, the patch is wrapped about an expansion device which is typically a mechanically operated expander plug and is subsequently lowered through the production tubing to the uncovered perforation. Upon reaching the perforation the patch is expanded to seal the perforation. Typically the patch is held in place in the well casing by friction. However, in many wells there are one or more restrictions in the production tubing with the minimum restriction imposing a limit on the diameter of the unexpanded patch. During expansion of the patch, the radial thickness of the wall of the cylindrical steel sleeve decreases. In order to mitigate the risk of the expanded patch collapsing under the external pressure exerted by the formation fluids, the maximum expansion ratio for a tubular metal patch is about 30%. A problem therefore arises when the minimum restriction in the production tubing is small compared with the diameter of the wellbore as it may not be possible to expand the patch to form a fluid-tight seal with the casing or the wall of an open hole wellbore without exceeding the maximum expansion ratio.

Accordingly, it is an object of the present invention to provide a patch comprising a metal tube that is capable of being deformed such that in its deformed state the patch can pass through a restriction in a wellbore to the location where the patch is to be deployed. Once at the desired location in the wellbore, the patch may be reformed into a substantially tubular shape having an outer diameter greater than the minimum restriction in the wellbore and subsequently at least a portion of the reformed tubular patch may be expanded to form a fluid tight seal with the wall of the wellbore without exceeding the maximum expansion ratio.

It is a further object of the present invention to provide a method and apparatus for installing such deformable patches in fluid-tight annular sealing engagement with the wall of a wellbore.

Thus, according to a first embodiment of the present invention there is provided a patch for deployment in a wellbore at a location below a restriction,  $D_1$ , the patch comprising a metal tube that is capable of being deformed into an irregularly shaped tube having a maximum external diameter,  $D_2$ , and of being subsequently

reformed into a tubular shape having an external diameter,  $D_3$ , wherein  $D_2$  is less than  $D_1$  and  $D_3$  is greater than  $D_1$ , and wherein at least a section of the reformed tube is capable of being plastically expanded to an external diameter,  $D_4$ , to form a fluid tight annular seal with the wall of the wellbore and the expansion ratio,  $[(D_4-D_3)/D_3] \times 100$ ,

5 is less than the maximum expansion ratio for the metal tube.

Suitably, the deformed tube may be reformed into a tubular shape of substantially uniform external diameter, preferably, into its original tubular shape, prior to expanding at least a section of the reformed tube. Alternatively, a section of the deformed tube may be reformed and expanded prior to reforming and optionally 10 expanding the remainder of the deformed tube.

Suitably, production tubing is run into the wellbore and the patch is deployed in the wellbore through the production tubing. Typically, the production tubing has one or more restrictions therein such that the deformed patch must be capable of passing through the minimum restriction in the production tubing.

15 Preferably, the metal tube is deformed into a longitudinally corrugated tube. It is also envisaged that the metal tube may be deformed into any other shape that is capable of passing through the restriction,  $D_1$ . Suitably, the metal tube may be deformed to a size smaller than the restriction,  $D_1$ , using a set of rollers located above the wellhead.

20 Typically, the deformed metal tube has a maximum external diameter,  $D_2$ , that is slightly less than the restriction,  $D_1$ , for example 5 to 10% less than the restriction,  $D_1$ . At least a portion of the reformed tubular patch is capable of being plastically expanded to form an annular fluid tight seal with the wall of the wellbore without exceeding the maximum expansion ratio for the metal tube. Typically, the total 25 expansion ratio for the deformed tube,  $[(D_4-D_2)/D_2] \times 100$  is 40 to 50% with the proviso that the maximum expansion ratio,  $[(D_4-D_3)/D_3] \times 100$ , for the reformed metal tube is not exceeded. Typically, the maximum expansion ratio for the reformed metal tube is 30%, for example 25 to 30%.

Suitably, the patch may be deployed in a cased wellbore or an open hole 30 wellbore with the patch forming a fluid tight seal with the wall of the casing or the open hole respectively. The patch may also be deployed in a wellbore that is provided with a liner with the patch forming a fluid tight seal with the wall of the liner. It is

envisioned that a plurality of portions of the reformed patch may be expanded to form a plurality of annular seals. Alternatively, the deformed tubular patch may be reformed and expanded along substantially the entire length thereof.

- Suitably, the metal tube of the patch is formed from steel, preferably a low carbon steel or other suitable metal alloys. Preferably, the metal tube may be coated with a resilient material, preferably an elastomeric material, to provide an improved seal with the casing of a cased wellbore or with the wall of an open hole wellbore upon expansion of the reformed tube. Preferably, the elastomeric material is resistant to the well environment, i.e. temperature, pressure, well fluids, and the like. Suitably, the elastomeric material is selected from rubber (for example, silicone rubber), polymers of ethylene-propylene diene monomer (EPDM), polytetrafluoroethylene, polyphenylene sulfide, and perfluoroelastomers.

As discussed above, the thickness of the wall of the metal tube decreases as it is expanded. The required thickness of the wall after expansion is a function of the diameter of the wellbore and the yield and tensile strength of the metal forming the tube. In general, as the wellbore diameter increases it is necessary to increase the thickness of the wall of the expanded metal tube in order for the tube to apply sufficient force to the wall of the wellbore to seal the perforations or the open hole. Preferably, the thickness of the wall of the expanded metal tube is in the range 0.25 to 0.5 inches for an expanded tube having an internal diameter of 6 to 8 inches. Typically, the thickness of the coating of resilient material is in the range 0.05 to 0.2 inches, for example, about 0.1 inch.

Suitably, the patch may be from 10 to 1000 feet in length, preferably, 30 to 600 feet, more preferably 50 to 300 feet, for example, 100 to 200 feet. The patch may be formed from tubular metal sections having a length of 5 to 40 feet, preferably 20 to 30 feet. The sections of the patch may be joined together using conventional flush joints having a maximum diameter smaller than the minimum restriction in the wellbore, in which case there is no requirement to deform the joints. Alternatively, the sections of the patch may be joined together using deformable joints. Preferably, the deformable joints are reformable. Suitably, the reformable joint comprises a male connection on a first tubular metal section of the patch and a female connection on a second tubular metal section of the patch where the male and female connections are

provided with interlockable complementary formations such that when the joint is deformed and subsequently reformed, the complementary formations of the male and female connections do not break apart. For example, the male and female connections may be provided with interlockable dovetailed threads. Preferably, the reformable 5 joint is capable of being expanded to allow the patch to be expanded along its entire length. Suitable expansion joints are well known to the person skilled in the art and may be adapted to be interlockable, for example, by employing dovetailed threads, as described above.

The deformed metal tube may be reformed and at least a portion thereof 10 plastically expanded using any suitable techniques known to the person skilled in the art. By plastically expanded is meant that the expanded shape is maintained when the expansion pressure is no longer being applied. Thus, the deformed metal tube may be reformed and plastically expanded by applying hydraulic pressure to the interior of the deformed tube via a rig pump or a downhole pump suspending from wireline. 15 Alternatively, the deformed metal tube may be reformed and plastically expanded using an expandable mandrel run on coiled tubing. The deformed metal tube may also be reformed and plastically expanded using an expansion tool having hydraulically actuated, radially expandable members, as described in US 2001/0045284, which is herein incorporated by reference. Suitably, this expansion 20 tool is run on coiled tubing or wireline. It is also envisaged that the deformed metal tube may be reformed and plastically expanded using an expansion tool having electrically actuated, radially expandable members that is run on wireline, as described below.

In a second embodiment of the present invention there is provided a patch for 25 deployment in a wellbore at a location below a restriction,  $D_1$ , the patch comprising a metal tube having an outer diameter small enough to pass through the restriction wherein at least one section of the metal tube is of a reduced inner diameter and hence increased wall thickness,  $t_1$ , compared with the wall thickness,  $t_2$ , of adjacent sections of the metal tube (i.e.  $t_1 > t_2$ ) and wherein the at least one section of metal tube of 30 increased wall thickness is capable of being plastically expanded to form an annular ring seal between the patch and the wellbore.

Preferably, the patch is deployed through production tubing, as described.

above for the first embodiment of the present invention.

Preferably, after expansion of the section of tube of increased thickness the inner diameter of the expanded section of tube is substantially the same as the inner diameter of the adjacent non-expanded sections of the metal tube. Preferably, prior to expansion the patch has a substantially uniform outer diameter.

The section(s) of metal tube of increased wall thickness may be expanded against the metal casing of a cased wellbore to form a metal to metal annular ring seal. It is also envisaged that the section(s) of tube of increased wall thickness may be coated with a resilient material, preferably, an elastomeric material in which case the patch may be deployed in an open hole wellbore. Suitable elastomeric material are as described above.

Preferably, the section(s) of metal tube of increased wall thickness,  $t_1$ , may be provided with an annular recess or groove on the outer surface thereof having an annular resilient sealing member, for example, an O-ring located therein. Preferably, the annular resilient sealing member is formed of an elastomeric material. Suitable elastomeric materials are as described above. Expansion of the section(s) of the metal tube will force the annular resilient sealing member against the casing of a cased wellbore or against the wall of an open hole wellbore thereby forming a fluid-tight seal.

The patch of this further embodiment of the present invention may be deployed using any conventional expansion tool, as described above for the deformable patch, or by using an expansion tool comprising electrically actuated, radially expandable members that is described below.

In yet a further embodiment of the present invention there is provided an apparatus for expanding a tubular metal patch in a wellbore comprising:  
at least one radially extendible slip for gripping the inner wall of the tubular metal patch;  
an expander tool, disposable in the tubular metal patch, the expander tool being rotatable and having a plurality of elements radially extendible therefrom and arranged to contact the inner wall of the tubular metal patch,  
an electric motor for actuating the at least one radially extendible slip, for actuating a means for radially extending the plurality of radially extendible elements of the

expander tool, and optionally, for actuating a means for rotating the expander tool.

An advantage of the apparatus of this embodiment of the present invention is that it provides improved control over the radial extension of the plurality of radially extendible elements when compared with the hydraulically actuated device of US

5 2001/0045284.

The apparatus for deploying the patch may be run into the wellbore on conventional wireline which provides support for the weight of the apparatus and electric power for actuating the components of the expansion tool. Alternatively, the apparatus may be run on electric coiled tubing. Suitable electric coiled tubing is

10 described in UK patent application no: GB 2359571-A which is herein incorporated by reference. Where the apparatus is run into the wellbore on conventional wireline or on electric coiled tubing, the apparatus is provided with an electric motor, preferably, a dedicated electric motor, for actuating a means for rotating the expander tool. It is also envisaged that the apparatus may be run into the wellbore on a drill

15 string where the rotation of the drill string is used to provide rotation to the expander tool. Suitably, the expander tool is provided with a mechanical means for radially extending and retracting the extendible elements, for example, a jack mechanism.

Preferably, the mechanical means for radially extending and retracting the extendible elements is actuated by a dedicated electric motor. It is also envisaged that the

20 expander tool may be provided with an electrically powered means for radially extending and retracting the extendible elements. Suitably, the power supply for the electrically powered means for radially extending and retracting the extendible elements is located downhole, preferably, comprising a component of the expansion tool. During this running in operation, the tubular metal patch is gripped by the least

25 one radially extendible "slip". Preferably, the at least one radially extendible "slip" engages with and grips the inner wall of the tubular metal patch at the upper end thereof. Suitably, the at least one radially extendible "slip" comprises teeth or other gripping elements. Preferably, the apparatus is provided with a plurality of "slips", preferably 2 to 4 slips. Suitable "slips" for use with the patch would be well known to

30 the person skilled in the art.

Suitably, as an alternative to holding the patch at the desired location using at least one radially extendible slip, an upper section of the patch may be fixed in

position in the wellbore prior to forming the annular seal by means of a plurality of mechanical dimples, for example circular shaped dimples arranged circumferentially around the tubing at the desired location, as described in Figure 16 of US 6,223,823 which is herein incorporated by reference. Suitably, at least 3 dimples are provided.

5      The mechanical dimples may be activated by means of internal pressure applied by the expansion tool of the present invention. Preferably, a resilient annular sealing member is provided in the vicinity of the dimples to impart an anchoring surface against which the dimples engage thus improving the contact between the patch and the walls of the wellbore.

10     Once the apparatus has been lowered to a level proximate a perforation or a damaged section of casing or a section of open hole wellbore, the radially extendible elements of the expander tool are electrically actuated and contact the inner wall of the patch. The patch is then expanded by rotating the expander tool and gradually radially extending the extendible elements until the patch engages with the wall of the wellbore thereby forming an annular fluid tight ring seal. Suitably, the radially extendible elements of the expander tool are rollers that are moved radially outwards by means of an electrically actuated jack mechanism. Suitably, the jack mechanism is actuated by means of a dedicated electric motor.

15

Preferably, the expander tool is provided with an electrically actuated mechanical means for moving the radially extendible elements of the expander tool longitudinally within the tubular patch thereby extending the annular seal. Preferably, the mechanical means is a screw mechanism. Preferably, the screw mechanism is actuated by means of a dedicated electric motor.

20     Preferably, the annular ring seal is formed by partially expanding a portion of the tubular metal patch and then longitudinally extending the expanded portion before further expanding the tubular metal patch and then further longitudinally extending the expanded portion of the tubular metal patch and repeating these steps until the patch engages with the wall of the wellbore and a fluid tight annular ring seal is formed between the patch and wellbore wall. The patch is now locked in place in the wellbore and the radially extendible members may be retracted and the slips retracted (unset) before moving the apparatus to a new position in the patch. The slips are then reset and a further annular ring seal may be formed as described above. As would be

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apparent to the person skilled in the art, the apparatus of the present invention may be used to form any desired number of annular "ring" seals. Alternatively, the apparatus of the present invention may be used to expand the entire patch to form an annular seal along the entire length thereof by gradually moving the expander tool through the

5 patch. Where the apparatus is used to form one or more annular ring seals, the seal(s) preferably has a curved profile to mitigate the risk of the seal being put under stress which can lead to increased corrosion of the casing and patch.

Preferably, the apparatus is provided with sensors for monitoring the expansion of the patch and the position of the tool in the wellbore.

10 When the apparatus of the present invention is used to reform a deformed tubular patch, for example, a longitudinally corrugated tube, at least a portion of the tube is first reformed into its original tubular shape using the radially extendible elements before expanding the portion of reformed tube to form an annular "ring" seal between the patch and the casing. Preferably, the deformed tubular patch is reformed

15 along the entire length thereof. Suitably, a plurality of portions of the reformed tubular patch may be expanded using the apparatus of the present invention to form a plurality of "ring" seals or alternatively, the entire tubular patch may be expanded to form an annular seal with the wall of the casing or the open hole wellbore.

It is also envisaged that a patch comprising an inner metal tube and an outer  
20 resilient annular sealing member may be deployed using the apparatus of the present invention. Suitably, the inner metal tube is formed from steel, preferably, carbon steel. As discussed above, the thickness of the inner metal tube will be a function of the diameter of the wellbore and the yield and tensile strength of the metal forming the tube. Preferably, the thickness of the inner metal tube is in the range 0.25 to 0.5 inches. Preferably, the outer resilient annular sealing member is formed from an  
25 elastomeric material that is resistant to the well environment, i.e. temperature, pressure, well fluids, and the like. Suitable elastomeric materials are as described above. Typically, the thickness of the outer resilient annular seal member is in the range 0.05 to 0.15 inches, for example, about 0.1 inches.

30 The outer resilient annular sealing member may be a sheath extending along substantially the entire length of the patch or may comprise at least one sealing ring. Typically the patch may be provided with a plurality of resilient sealing rings

arranged at locations along the length thereof where it is desired to form an annular ring seal with the casing or the wall of the open hole wellbore. Typically, the resilient sealing rings have a longitudinal length of 1 to 5 inches. Suitably, the resilient sealing rings are arranged at the upper and lower ends of the patch although the resilient

5 sealing rings may also be arranged at intervals along the patch, for example, every 0.5 to 2 feet.

In a further aspect of the present invention, the apparatus of the present invention may be used to form an annular ring seal between a liner and a casing such that the annular ring seal acts as a liner hanger in addition to sealing the annulus

10 between the liner and casing. Thus, the ring seal must be capable of taking the weight of the liner. Preferably, the "liner hanger" comprises a plurality of ring seals.

The present invention will now be illustrated by reference to Figures 1 to 10.

Figure 1 is a transverse cross-sectional view illustrating a deformable tubular patch in an undeformed state 1, and deformed into a longitudinally corrugated tube 2 having a maximum outer diameter,  $D_2$  less than the minimum restriction 3 in a wellbore. Figure 2 shows the patch reformed into its original tubular shape 4 and in an expanded state 5. Figure 3, illustrates a deformable and expandable dovetail joint 6 for joining sections of the deformable tubular metal patch.

Figure 4 is a longitudinal cross sectional view showing a tubular metal patch

20 10 in position in a cased wellbore 11 prior to expansion of the patch against the casing wall 12. The patch 10 is provided with a section 13 of decreased internal diameter and hence increased wall thickness. Figure 5 shows the patch after a metal to metal ring seal 14 has been formed at the location of the section of decreased internal diameter.

25 Figure 6 illustrates a modified patch of the type shown in Figures 4 and 5 wherein the section 13 of patch of decreased internal diameter and hence increased wall thickness is provided with an external groove 14 adapted to receive an O-ring, 15, formed from an elastomeric material. Figure 7 shows the patch in annular ring sealing engagement with the walls of a wellbore 16 which may be either a cased

30 wellbore or an open hole wellbore.

Referring to Figure 8, a production tubing 20 having a restriction 21 is positioned within the casing 22 of a wellbore. A liner 23 is hung from the casing 22

via a casing hanger 24. An apparatus for deploying a tubular metal patch 25 is lowered into the wellbore through the production tubing 20 suspended from a wireline 26. The apparatus comprises a connector 27, a controller 28, a first electric motor 29 for actuating a screw mechanism (not shown) for radially extending and retracting 5 slips 30, and an expander tool comprising a jack mechanism 31 for radially extending and retracting rollers 32, and a rotatable shaft 33 that extends from a second electric motor 34 through patch 25 to a third electric motor 35. The second electric motor 34 actuates the jack mechanism 31 and a means (not shown) for driving the rotatable shaft 33 while the third electric motor 35 actuates a screw mechanism (not shown) for 10 moving the rollers 32 in a longitudinal direction within the patch 25. The slips 30 are shown in their radially extended position gripping the tubular metal patch 25. Once the patch 25 is in the desired location in the wellbore, the shaft 33 is rotated and the rollers 32 are gradually radially extended to expand the patch until the patch forms an annular fluid tight seal with the wall of the liner 23. At various stages during the 15 radial expansion of the rollers 32, the third electric motor 35 actuates the screw mechanism to move the rollers upwardly and downwardly within the patch 25 thereby extending the annular seal. Figure 9 shows the result of this operation with a section of the patch 25 expanded to form an annular seal 36 with the wall of liner 23.

Referring to Figure 10, the rollers 32 and slips 30 are retracted before moving the 20 expansion tool to a new position in the patch and radially extending the slips 30 to grip the inner wall of the patch. The expansion tool is then actuated to expand the new section of patch, as discussed above. The third electric motor 35 may be provided with a "steady" having a centraliser 37 that engages with the liner 23. This operation may be repeated until the entire lower section of the patch has been 25 expanded against the wellbore wall. As shown in Figure 11, the apparatus may then be moved upwardly through the wellbore until the expander tool is located in the upper 38 unexpanded part of the patch 25. The slips 30 are then radially extended to engage with the wall of the casing 22 and the expander tool actuated as described above to expand the upper section 38 of the tubular metal patch. The rollers 32 and 30 slips 30 may then be retracted and the apparatus removed from the wellbore by pulling the wireline leaving behind the expanded patch in annular sealing engagement with the wall of the liner 23.

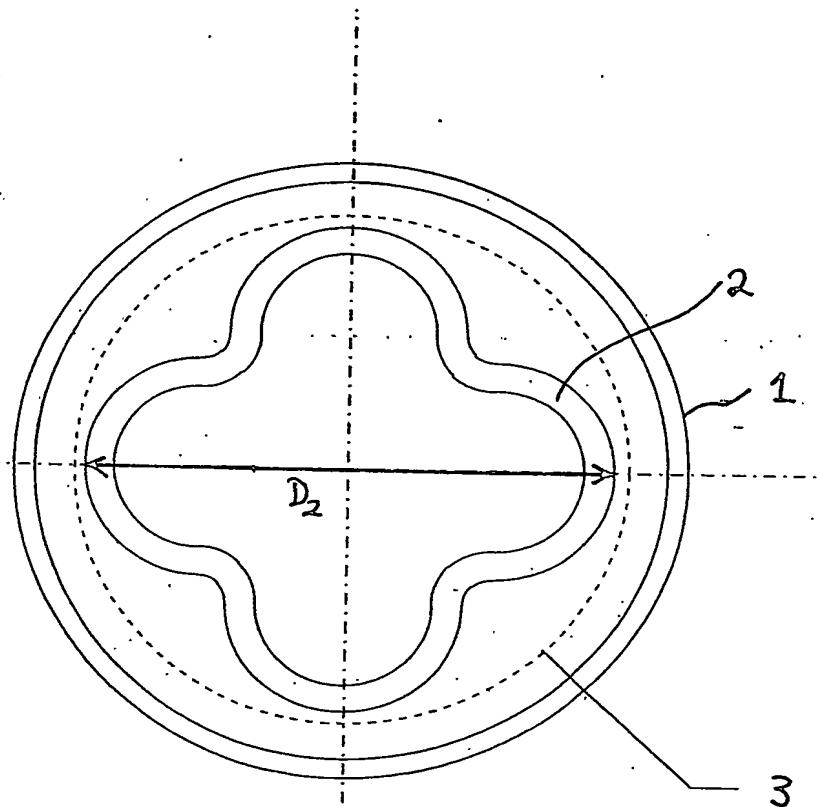


FIG 1

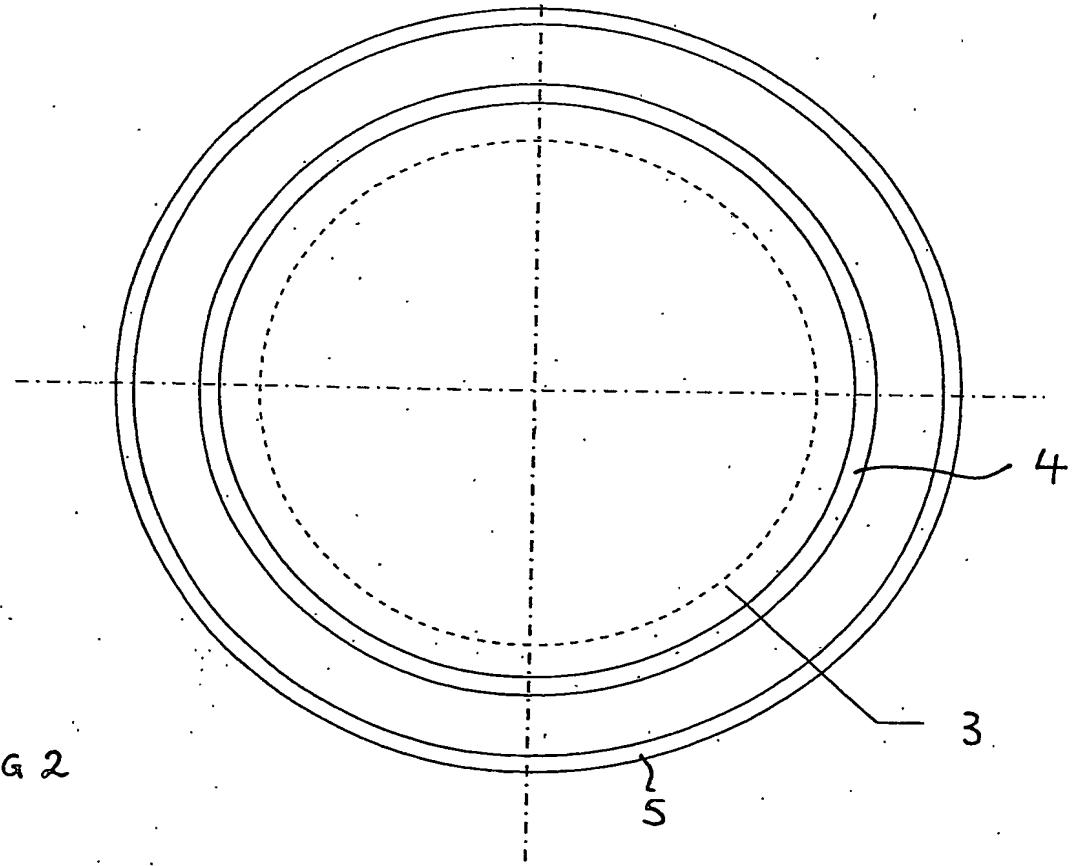


FIG 2

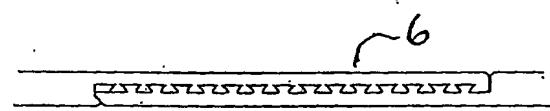
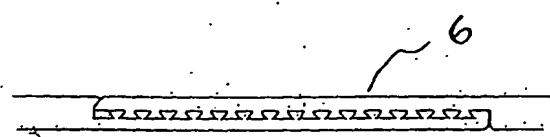


FIG 3



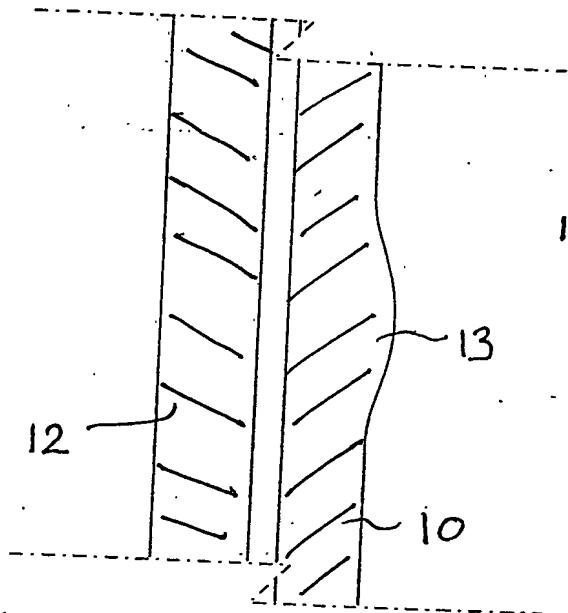


FIG. 4

Centre line  
of well

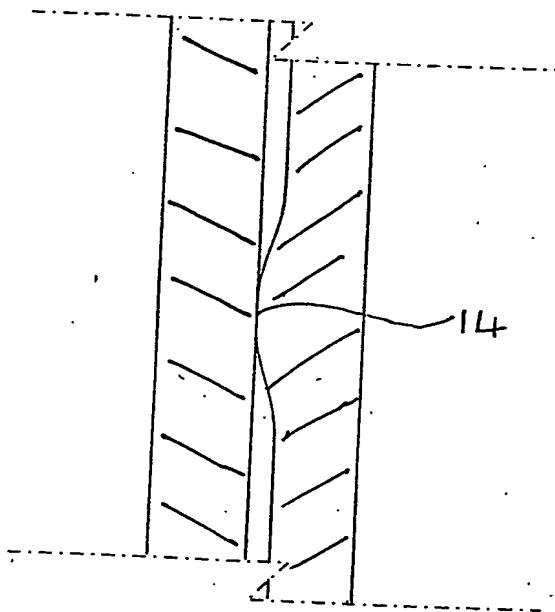


FIG. 5

Centre line  
of well

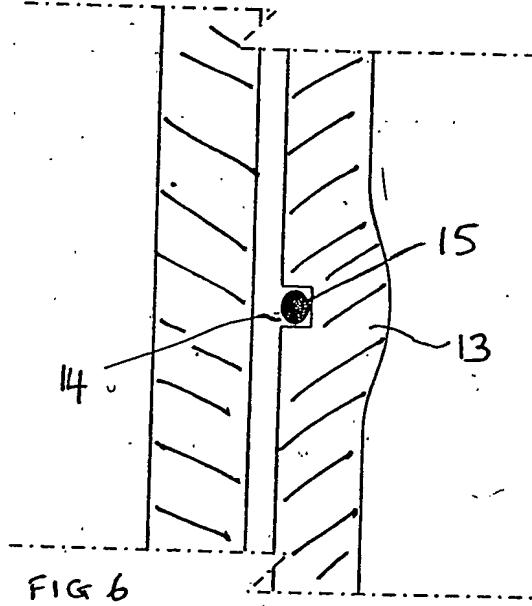


FIG 6

Centre line  
of well

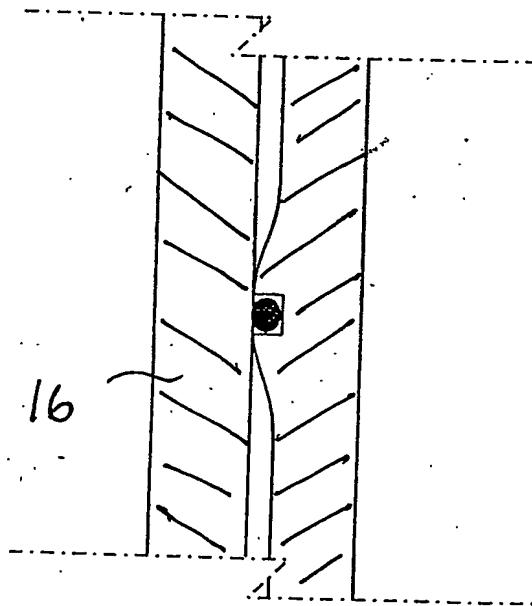
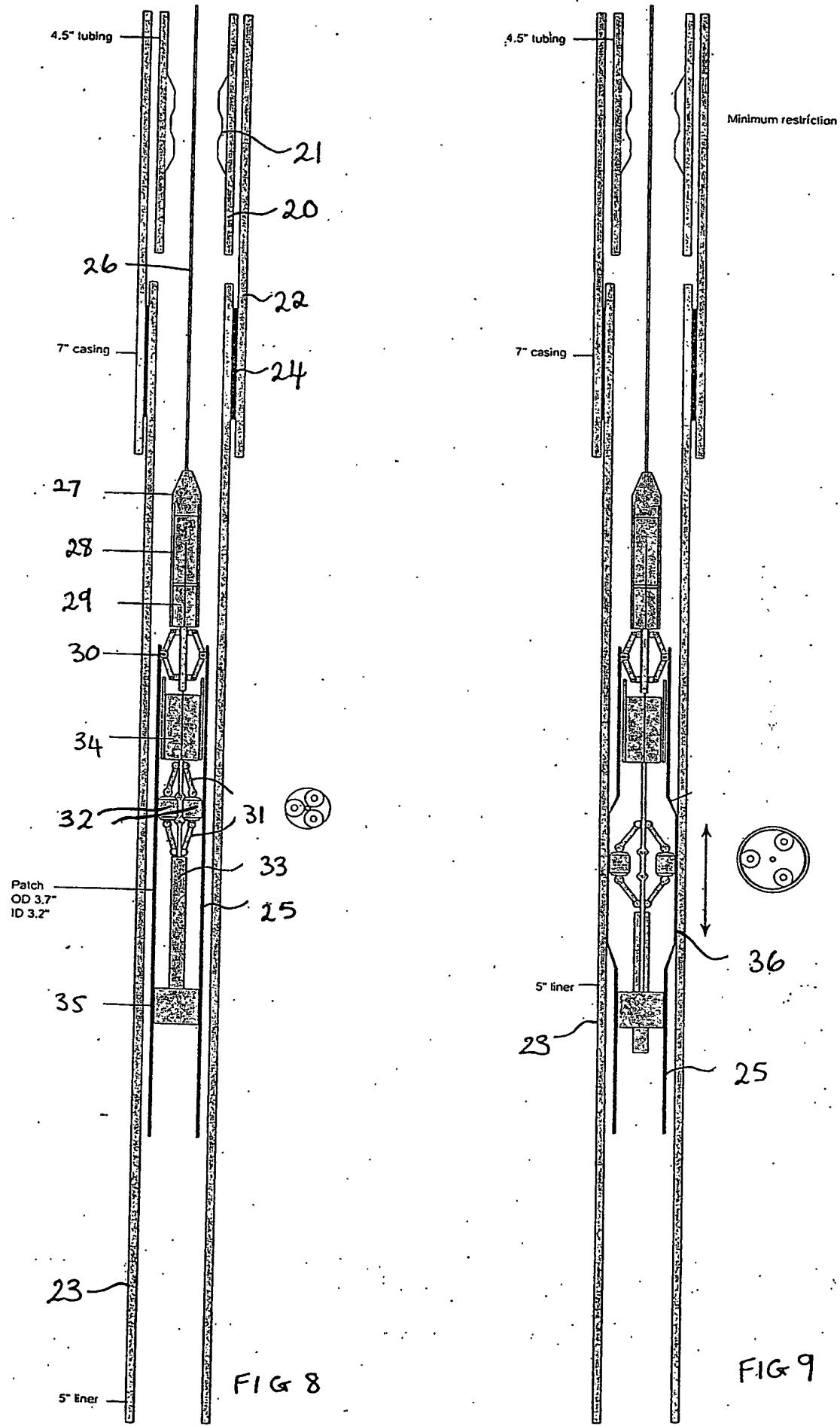
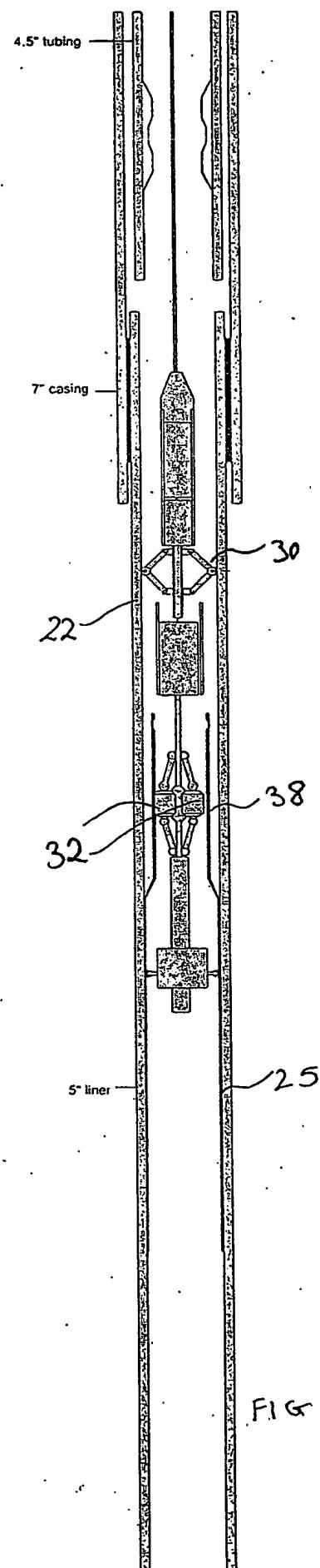
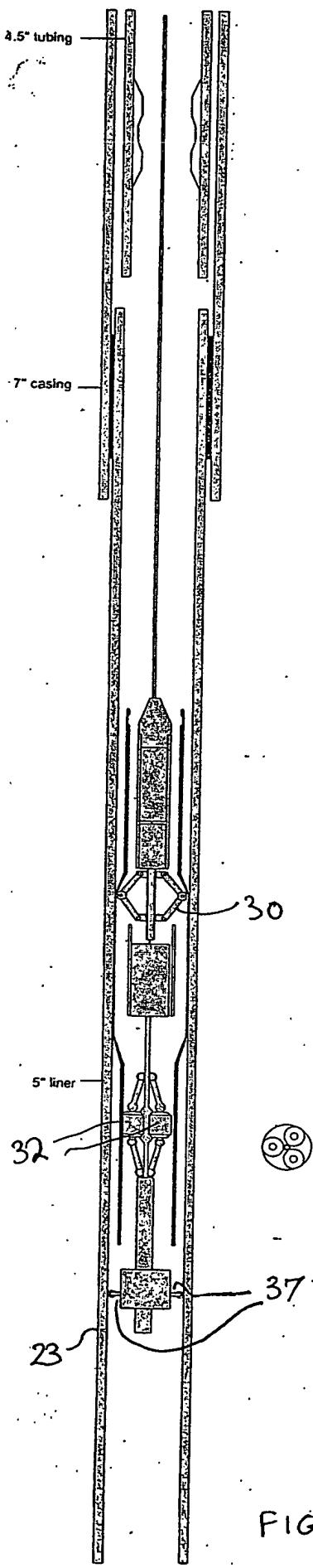


FIG 7

Centre line  
of well





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